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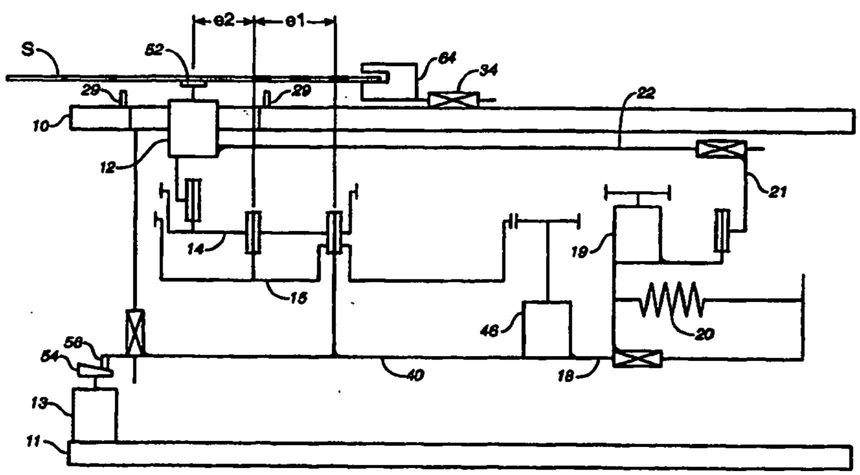

(57) Abstract

A prealigner (16) with a first rotating member (14) having a second rotating member (15) mounted therein such that the axis of rotation of the second rotating member (15) is displaced or offset from the axis of rotation of the first rotating member (14). The second rotating member has a substrate holder (52) mounted therein such that the axis of rotation of the substrate holder (52) is displaced or offset from the axis of rotation of the second rotating member (15). When the offset distance between the axes of rotation of the first rotating member (14) and the second rotating member (15) is equal to the offset distance between the axes of rotation of the second rotating member (15) and the chuck (52) then the center of the chuck (52) can be moved to any location within a circle with a radius equal to the sum of the two offset distances. When the two offset distances are not equal, then the center of the chuck (52) can be moved to any location within a zone bounded by an outer circle having a radius equal to the sum of the two offset distances and an inner circle having a radius equal to the absolute value of the difference of the two offset distances.

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SUBSTRATE PREALIGNER

Background of Invention

Field of the Invention

The invention relates to an apparatus and method for performing substrate prealignment in the semiconductor wafer and flat panel display transporting and processing fields.

Brief Description of the Related Art

In the semiconductor wafer and flat panel display processing fields, robot arms with end effectors are used in moving substrates including semiconductor wafers, flat panels, reticles, and the like, to and from cassettes and workstations where various processing steps take place. The robot end effector and the workstations or cassettes where the substrates are held must be properly aligned with one another so that the substrates can be transferred and positioned properly without damage.

Several different types of robot linkages are known in the art. These linkages include telescoping arms, rotatable link arms, and isosceles triangle-type linkages. Pulleys, belts, and motors are generally utilized to move the links of the robot arm with respect to one another and to move a robot end effector or hand located at the end of the arm which is used to grasp and transport a substrate. In use, the robot arm is extended to pick up a substrate located in a cassette or at a workstation with the end effector, generally by suction. The arm is then retracted and rotated to the position of another cassette or workstation. The robot arm

carrying the substrate is then advanced to another cassette or workstation where the substrate is deposited.

Prealigning is a process of dealing with a problem of angular and linear misalignment of a substrate by orienting and centering the substrate on the robot end effector. This problem is particularly prevalent when dealing with flat panel displays because the flat panels are often present in cassettes with a certain degree of angular and linear misalignment. During prealignment, the substrate is oriented and centered so that a mark such as a flat or notch of the substrate is set at a predefined angled and a center of the substrate is positioned at a predefined location on the end effector. Prealigning ensures that successively processed substrates are all oriented with the mark in the same direction and are centered during processing.

Prealigning is generally achieved by placing a substrate on a chuck of a prealigner having light sensors such as CCD sensors and using the chuck to rotate the substrate over the light sensors to detect the degree of misalignment. The chuck then may be used to center and align the substrate on the robot end effector. Alternatively, the robot end effector alone may be used to center the substrate on the chuck, or a combination of the robot and the chuck may be used.

Known prealigners have certain inherent limitations because the chuck is supported on linear bearings and is actuated by leadscrews. The design of these prealigners requires bidirectional (i.e., reversible) motion of the actuator associated with the leadscrews which in turn require hard stops at both ends of the working range. When a hard stop is encountered, an impact is produced which destroys the tuning and calibration of the sensor measuring system. Similarly, reversal of the actuator can generate backlash which has an adverse effect on accuracy.

Summary of the Invention

The present invention achieves planar movement of the chuck or substrate holder in a horizontal plane with two off-centered rotating members using uni-directional endless actuation to avoid hard stops and backlash which destroy the accuracy of the prealigner. The invention utilizes three vertical axes of rotation which are displaced from one another by two off-center distances. In one embodiment, the device of the present invention comprises a first rotating member having a second rotating member mounted therein such that the axis of rotation of the second rotating member is displaced or offset from the axis of rotation of the first rotating member. The second rotating member having a chuck mounted therein such that the axis of rotation of the chuck is displaced or offset from the axis of rotation of the second rotating member. If the offset distance between the axes of rotation of the first rotating member and the second rotating member is equal to the offset distance between the axes of rotation of the second rotating member and the chuck then the center of the chuck can be moved to any location within a circle with a radius equal to the sum of the two offset distances. If the two offset distances are not equal, then the center of the chuck can be moved to any location within a zone bounded by an outer circle having a radius equal to the sum of the two offset distances and an inner circle having a radius equal to the absolute value of the difference of the two offset distances.

In one aspect of the present invention, there is provided a method of prealigning a substrate comprising placing the substrate on a substrate holder, rotating the substrate with respect to a sensor and controller to determine a displacement distance and displacement angle, removing the substrate from the substrate holder and repositioning the substrate holder with respect to the substrate using a first rotating member having a rotation axis offset from a rotation axis of a

second rotating member which second rotating member rotation axis is offset from a rotation axis of the substrate holder.

In another aspect of the present invention, there is provided a prealigner for a substrate comprising a first rotating member having a rotation axis, a second rotating member mounted on the first rotating member such that a rotation axis of the second rotating member is offset from the rotation axis of the first rotating member, a substrate holder mounted on the second rotating member such that a rotation axis of the substrate holder is offset from the rotation axis of the second rotating member, a sensor and controller which detects a position of the substrate with respect to the rotation axis of the substrate holder, a first actuator for rotating the first rotating member in response to the sensor and controller to reposition the first substrate holder and a second actuator for rotating the second rotating member in response to the sensor and controller to reposition the first substrate holder.

Brief Description of the Drawings

The invention will now be described in greater detail with reference to the preferred embodiments illustrated in the accompanying drawings, in which like elements bear like reference numerals, and wherein:

FIG. 1 is a diagrammatic sectional view of a first embodiment of the prealigner of the present invention;

FIG. 2 is a simplified diagrammatic representation of the prealigner of FIG. 1;

FIG. 3 is a top view of a misaligned substrate and an end effector of a robot positioned at a prealigner station;

FIGS. 4 and 5 are diagrammatic representations of the linear and angular quantities used to accomplish the planar movement of the chuck of the prealigner;

FIG. 6 is a diagrammatic sectional view of a second embodiment of the prealigner; and

FIG. 7 is a diagrammatic sectional view of a third embodiment of the prealigner.

Detailed Description of the Preferred Embodiments

In order to address the problem of misalignment of a substrate S with the center of a robot end effector 66 (FIG. 3), the present invention comprises a prealigner 16 which detects a position of the substrate S with respect to the center of the chuck 52 and the end effector 66 and aligns the center of the substrate to coincide with the center of the end effector 66. The adjustment of each of the substrates allows the substrates to be removed from and delivered to various cassettes and workstations (not shown) of a substrate processing system without damage to each substrate. The invention is particularly applicable to transportation and processing of semiconductor wafers, flat panel displays, and reticles, but may also be used for other types of substrates.

The present invention uses two offset rotating members 14 and 15 and an offset rotating substrate holder or chuck 52 mounted on the shaft of the motor 12. Motor 12 is mounted within and off-center from the axis of rotation of rotating member 14. The motor 12 is rotatably mounted on ball or other type of bearings 36. The shaft of motor 12 is hollow to provide vacuum feeding to the chuck 52. Vacuum is fed through the shaft to the chuck 52 using a vacuum feeding device 60 located under the encoder 62 of motor 12. The power and signal cables (not shown) for the motor 12 pass inside of the bearings 36. Rotating member 14 is mounted within and off-center of the axis of rotation of rotating member 15. The rotating member 14 is rotatably mounted on ball or other type of bearings 38. Similarly, rotating member 15 is rotatably mounted to the body 40 of the prealigner 16 on ball or other type of bearings 42. This configuration provides

two off-center distances e1 and e2. The first off-center distance e1 being the distance between the axis of rotation of the rotating member 15 and the axis of rotation of the rotating member 14. The second off-center distance e2 being the distance between the axis of rotation of the rotating member 14 and the axis of rotation of the chuck 52.

Rotating member 15 is actuated through a timing belt 44 extending between the pulley 28 of the motor 46 (which is firmly attached to the body 40) and the rotating member 15. Bracket 17 is firmly attached to the body 40. The bracket 17 carries a spline 18 that allows the carriage 48 to move in a direction perpendicular to the axis of rotation of the rotating member 14. The rotating member 14 is actuated through a timing belt 50 extending between the pulley 30 of the motor 19 and the rotating member 14. The motor 19 is firmly attached to the carriage 48 that moves translationally along the spline 18. Belt tension in timing belt 50 is maintained by springs (not shown) on the carriage 48.

Spline 21 is mounted on the carriage 48 of the spline 18 on a ball or other type of rotational bearing. The plate 22 is attached to the carriage of the spline 21 allowing the plate 22 to translate and rotate with respect to spline 18. The stator of motor 12 is firmly attached to the distal end of plate 22. In order to maintain accurate measurements with respect to the rotational position of the rotating members 14 and 15, actuation flag 23 is firmly attached to the rotating member 14 with a corresponding sensor 24 being firmly attached to the carriage 48 on spline 18 and actuation flag 25 is firmly attached to the rotating member 15 with a corresponding sensor 26 being firmly attached to the body 40.

In one embodiment, the body 40 and all of its constituent parts just described move up and down on linear bearings (not shown) along the posts (not shown) which support the lower plate 11 and upper plate 10 in spaced relationship to each other. Cam 54 is mounted on a bearing on the lower plate 11 and is actuated by a motor and timing belt (not shown). Cam follower 56 firmly attached to the body 40 through bracket 58 transforms the rotation of cam 54 into a vertical

motion of the chuck 52. In another embodiment as shown in FIG. 6, the body 40 and all of its constituent parts can be fixed vertically and the pins 29 move up and down to raise and lower the substrate S with respect to the chuck 52.

A plurality of pins 29 are provided on the upper plate 10 of prealigner 16. The pins 29 hold the substrate in position when the chuck 52 moves down below the top surface of the pins 29. Vacuum is provided to the pins 29 through a vacuum feeding path embedded in the upper plate 10 so that the position of the substrate is maintained while the chuck 52 is moved in a planar fashion below the substrate in the manner to be described below.

A lighthouse 64 on top of the prealigner 16 moves in a horizontal plane towards and away from the center of the chuck 52. This allows the lighthouse to move over the edge of a substrate on the chuck 52 for detection and to clear away from the substrate and end effector 66 during their motion in and out of the prealigner 16. The lighthouse 64 is actuated by motor 34 (FIG. 2). Optionally, the lighthouse 64 can be moved along rail 68 (FIG. 1) manually to adjust the lighthouse position or the lighthouse 64 can be fixed to the upper plate 10 so as to be usable only for a given substrate diameter.

The lighthouse 64 includes a light source for positioning on one side of the substrate S and a light sensor, such as a linear CCD sensor, for positioning on an opposite side of the substrate. The substrate S is placed on the chuck 52 by the robot end effector 66 (FIG. 3) and the chuck 52 is used to rotate the substrate. The portion of the substrate S which is situated between the light source and the light sensor casts a shadow. During rotary motion of the substrate S by the chuck 52 the light sensor generates a signal proportional to the length of the substrate shadow. A controller collects the data from the light sensor at regular intervals and based on this information determines a displacement length D, a displacement angle T, and a flat angle α (FIG. 3). The displacement length D is the distance between the geometric center C_w of the substrate and the center C_c of the chuck. The displacement angle T is the angle between a line connecting the geometric

center C_w of the substrate to the chuck center C_c and the longitudinal axis 72 of the lighthouse 64 (i.e., with respect to a coordinate system attached to the prealigner) (as shown in FIG. 3) or the longitudinal axis 70 of the end effector 66 (i.e., with respect to a coordinate system attached to the end effector). The flat angle α is the angle between the longitudinal axis 72 of the lighthouse 64 (i.e., with respect to a coordinate system attached to the prealigner) (as shown in FIG. 3) or the longitudinal axis 70 of the end effector 66 and a line connecting the substrate reference mark or flat surface 32 to the chuck center C_c. The prealigner 16 can center and align the substrate S on the end effector 66 in a single step or in a multiple step manner as described below.

In one embodiment of the present invention, the prealigner 16 has one lighthouse 64 as shown in FIGS. 1 and 2. In other embodiments of the prealigner, there can be more than one lighthouse symmetrically placed around the center of the chuck 52. The principle advantages of two or more lighthouses is the reduced scanning time and the increased accuracy. When two, three, four, or more lighthouses are used, the magnitude of the angle which the substrate needs to be rotated by the chuck for data sampling is reduced proportionately depending on the number of lighthouses. For example, with two lighthouses, the substrate would only need to be rotated $360°/2=180°$, with three lighthouses, the substrate would only need to be rotated $360°/3=120°$, with four lighthouses, the substrate would only need to be rotated $360°/4=90°$ and so forth. The lighthouses may be actuated by a single motor or by separate motors (FIG. 7).

The aligning procedure is accomplished as follow. Initially, the substrate S is located on the end effector 66 with its center C_w off-center of the center of the end effector and its peripheral marker such as a notch or flat side 32 arbitrarily positioned with respect to the end effector longitudinal axis 70 or lighthouse longitudinal axis 72 (FIG. 3). The center C_c of the chuck and the center of the end effector 66 are precalibrated to be along the same vertical axis when the end effector 66 is initially moved over the chuck. The prealigner 16 of the present

invention is used to position the center C_w of the substrate S at the center C_c of the chuck and correspondingly at the center of the end effector 66. Prealigner 16 is also used to position the peripheral marker 32 of the substrate S at a given angle with respect to the body of the prealigner (i.e., the longitudinal axis 72 of the lighthouse) or with respect to the longitudinal axis 70 of the end effector 66. When the displacement distance D of the substrate center is smaller than the sum of both of the off-centered distances (e1 + e2) single step compensation may be used to align the substrate S. If the displacement distance D is greater than the sum of both of the off-center distances (e1 + e2), then multi-step compensation is used.

Initially (as shown in FIG. 1), the chuck 52 is moved to a position below the top of the vacuum pins 29 by using either the cam 54 and follower 56 or raising the pins 29 as described above. The lighthouse 54 is retracted to its outermost position to allow free motion of the end effector 66 and the substrate S to above the chuck 52. The misaligned substrate S is placed above the chuck 52 by the end effector 66. The initial position of the end effector 66 is calibrated such that the center of the end effector coincides with the center C_c of the chuck at the zero position. The zero position of the chuck 52 and the end effector 66 is referred to as the prealigner pickup position. The angle between the axis 70 of the end effector 66 and the axis 72 of the prealigner lighthouse 64 is known from precalibration of the system. The end effector 66 moves down and places the substrate S on the vacuum pins 29. The substrate S is grasped by the pins 29 using vacuum. The chuck 52 is moved up by the cam 54 or the pins 29 are lowered, accordingly, and the substrate S is grasped by the chuck 52 using vacuum. The lighthouse 64 moves towards the chuck 52 and substrate S to a position at which the CCD sensor and light source are over the edge of the substrate S. This position can be controlled by a set of activation flags that are preset such that the lighthouse 64 is positioned properly for the known substrate diameter. The chuck 52 and substrate S are rotated by the motor 12 so that the

substrate edge passes under the CCD sensor. The CCD sensor measures the length of the shadow left by the substrate and its edge.

The CCD sensor reports to the control system the displacement length D and the displacement angle T with respect to a coordinate system attached to the end effector (X_e, Y_e) or to the lighthouse (X_a, Y_a). In the example shown in FIGS. 3-5, D and T are reported with respect to the X_a, Y_a coordinate system. The off-center distances e1 and e2 are equal (i.e., e1=e2=e). In FIGS. 4 and 5, distance d is equal to the distance from the axis of rotation of the motor 46 to the axis of rotation of rotating member 15.

The following notation is used for the displacement compensation:

α	=	the angle at which the rotating member 14 should be rotated in order to move the center C_c of the chuck to the center C_w of the substrate;
β	=	the angle between a line connecting the axis of rotation of the rotating member 15 and the axis of rotation of the motor 46 and the position of the axis of rotation of the chuck if the motor 19 has moved at an angle M1;
γ	=	the angle between the X_a axis and the line connecting the rotating member 15 to the axis of rotation of the motor 46 after the motor 19 has been driven at an angle M1;
$\beta + \rho$	=	the angle at which the rotating member 15 should be rotated in order to move the center C_c of the chuck to the center C_w of the substrate;
θ	=	the angle between e1 and e2 when the center C_c of the chuck coincides with the center C_w of the substrate;
M1	=	the angle at which the motor 19 should be rotated in order to move the center C_c of the chuck to the center C_w of the substrate;

M2 = the angle at which the motor 46 should be rotated in order to move the center C_c of the chuck to the center C_w of the substrate; and

z1, z2, z3, z4 = the number of teeth on the respective pulleys associated with motor 19, motor 46, rotating member 14 and rotating member 15.

<u>Procedure for Finding M1 and M2</u>:

Calculate α = T - arccos (D/2e)

Calculate γ = arcsin ((esinα)/d)

Calculate β = γ (z2/z4)

Calculate θ = 2 arcsin (D/2e)

Calculate ρ = θ - α - γ

Calculate β + ρ

Calculate M1 = α (z3/z1)

Calculate M2 = (β + ρ) (z4/z2)

If the substrate displacement D is less than the working range of the chuck 52 (i.e., D < e1 + e2), the chuck 52 moves below the substrate S at a position T equals displacement angle and D equals displacement length so that the center C_c of the chuck is aligned vertically with the center C_w of the substrate. The chuck 52 is moved up to grasp the substrate S which is released by the vacuum pins 29. The chuck 52 and the substrate S are then moved together to the prealigner pickup position such that the center C_w of the substrate S is now aligned with the center C_c of the chuck and the center of the end effector 66. The chuck 52 and the substrate S are then rotated at P equals -flat angle to orient the substrate. The chuck 52 is then moved down below the top of the vacuum pins 29 such that the substrate S is grasped by the pins 29. The lighthouse 64 is moved to its outermost

position to allow safe passage of the substrate S and the end effector 66 away from the prealigner 16. The end effector 66 moves to the prealigner pickup position slightly below the substrate. The end effector 66 then moves up a small distance so as to transfer the aligned substrate from the vacuum pins 29 onto the end effector 66.

If the substrate displacement D is greater than the working range of the chuck 52 (i.e., D > e1 + e2), then the chuck 52 moves at a position T equals displacement angle, D equals e1 + e2. Chuck 52 is then moved up to grasp the substrate S which is released by the vacuum pins 29. The chuck 52, together with the substrate are moved to the prealigner pickup position. The chuck 52 and the substrate S are rotated again under the CCD sensor in order to find the new displacement distance, displacement angle, and flat angle. This is repeated until the substrate displacement is less than e1 + e2 and the chuck, together with the substrate, can be moved to the prealigner pickup position with the center C_w of substrate S aligned with the center C_c of the chuck 52 and the end effector 66. Then the chuck 52 and substrate are rotated at P equals -flat angle to orient the substrate.

The prealigner 16 of the present invention transforms the rotation of two rotating members into translation in the horizontal x-y plane. The translational motion of the chuck 52 is not restricted by mechanical stops. The kinematic scheme of the mechanism guarantees a limited range of motion of the chuck without the need to limit the motion of the actuators 19 and 46 for the rotating members 14 and 15. Therefore, impacts and backlash which could damage the calibration of the measuring system are avoided. The motor 19 and motor 46 may rotate in the same direction or may rotate in opposite directions but neither motor ever goes back on itself (i.e., irreversible motion) so as to avoid backlash for greater speed and accuracy. During operation, the rotating members 14 and 15 can rotate serially or simultaneously. Similarly, the chuck 52 is moved up and

down by a rotating cam 54 that has a continuous undulating surface so that no mechanical stop is required for its actuator.

While the invention has been described in detail with reference to the preferred embodiments thereof, it will be apparent to one skilled in the art that various changes and modifications can be made and equivalents employed, without departing from the present invention.

Claims:

1. A prealigner for a substrate, comprising:

a first rotating member having a rotation axis;

a second rotating member mounted on the first rotating member such that a rotation axis of the second rotating member is offset from the rotation axis of the first rotating member;

a substrate holder mounted on the second rotating member such that a rotation axis of the substrate holder is offset from the rotation axis of the second rotating member;

a sensor and controller which detects a position of the substrate with respect to the rotation axis of the substrate holder;

a first actuator for rotating the first rotating member in response to the sensor and controller to reposition the first substrate holder; and

a second actuator for rotating the second rotating member in response to the sensor and controller to reposition the first substrate holder.

2. The prealigner of Claim 1, wherein the offset between the rotation axis of the second rotating member and the rotation axis of the first rotating member is equal to the offset between the rotation axis of the substrate holder and the rotation axis of the second rotating member.

3. The prealigner of Claim 1 wherein the first and second actuators are uni-directional actuators.

4. The prealigner of Claim 1 wherein the sensor and controller translate perpendicular to the axis of rotation of the substrate holder.

5. The prealigner of Claim 1 further comprising means for raising and lowering the substrate holder.

6. The prealigner of Claim 1 further comprising a second sensor which detects the position of the substrate with respect to the rotation axis of the substrate holder.

7. The prealigner of Claim 1 further comprising a plurality of sensors spaced symmetrically around the substrate holder which detect the position of the substrate with respect to the rotation axis of the substrate holder.

8. A prealigner for a substrate, comprising:

a first rotating member having a rotation axis;

a second rotating member mounted on the first rotating member such that a rotation axis of the second rotating member is offset from the rotation axis of the first rotating member;

a first substrate holder mounted on the second rotating member such that a rotation axis of the substrate holder is offset from the rotation axis of the second rotating member;

a sensor and controller which detects a position of the substrate with respect to the rotation axis of the substrate holder;

a second substrate holder which holds the substrate while the first substrate holder is being repositioned;

a first actuator for rotating the first rotating member in response to the sensor and controller to reposition the first substrate holder; and

a second actuator for rotating the second rotating member in response to the sensor and controller to reposition the first substrate holder.

9. The prealigner of Claim 8 further comprising means for raising and lowering the second substrate holder.

10. The prealigner of Claim 8 further comprising means for raising and lowering the first substrate holder.

11. The prealigner of Claim 8 wherein the first and second actuators are uni-directional actuators.

12. A method of prealigning a substrate comprising:

placing the substrate on a substrate holder;

rotating the substrate with respect to a sensor and controller to determine a displacement distance and displacement angle;

removing the substrate from the substrate holder; and

repositioning the substrate holder with respect to the substrate using a first rotating member having a rotation axis offset from a rotation axis of a second rotating member which second rotating member rotation axis is offset from a rotation axis of the substrate holder.

13. The method of Claim 12 wherein the repositioning step comprises aligning the rotation axis of the substrate holder with a geometric center of the substrate by rotating the first rotating member an amount and the second rotating member an amount determined by the sensor and controller.

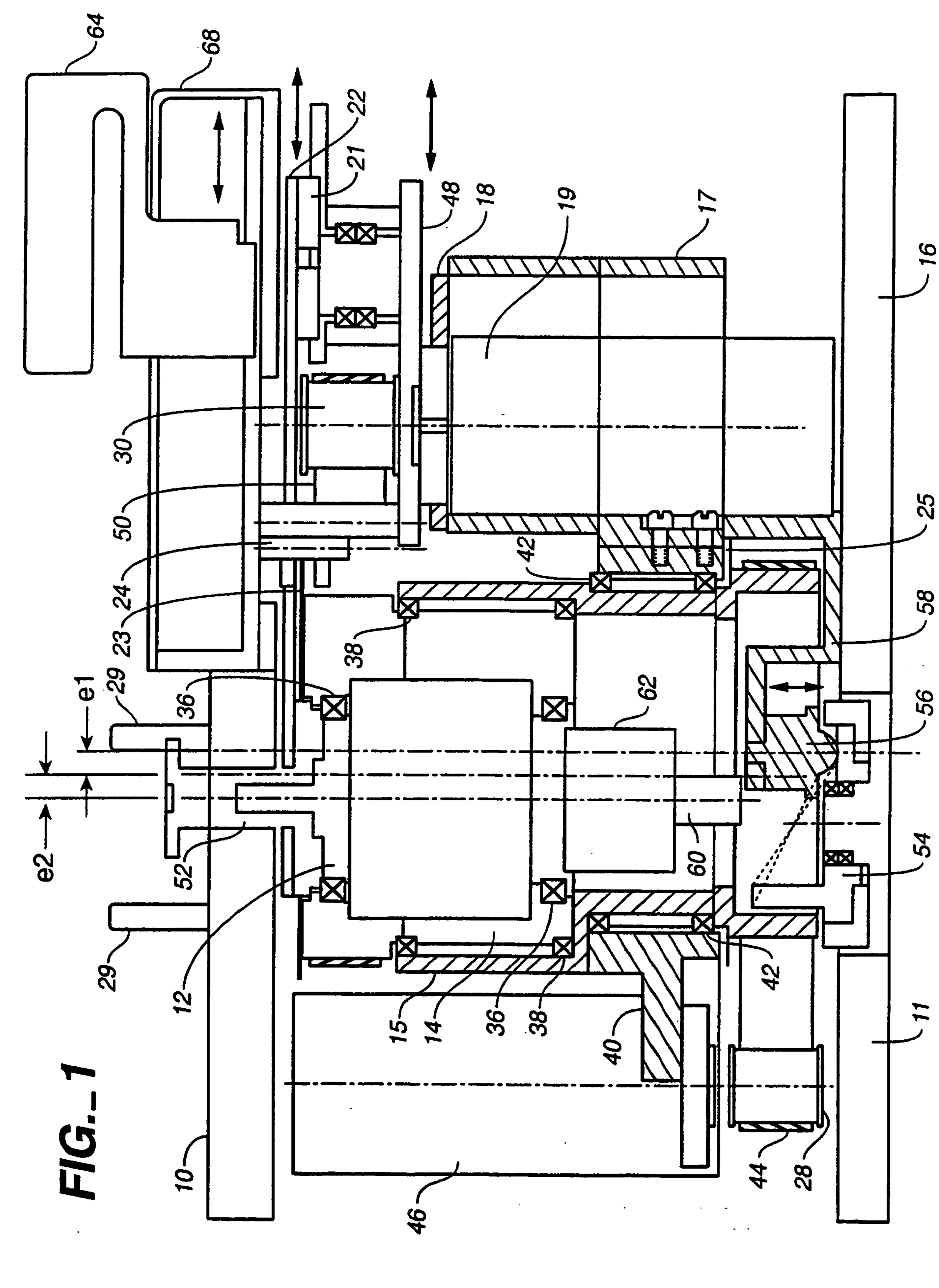
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FIG._1

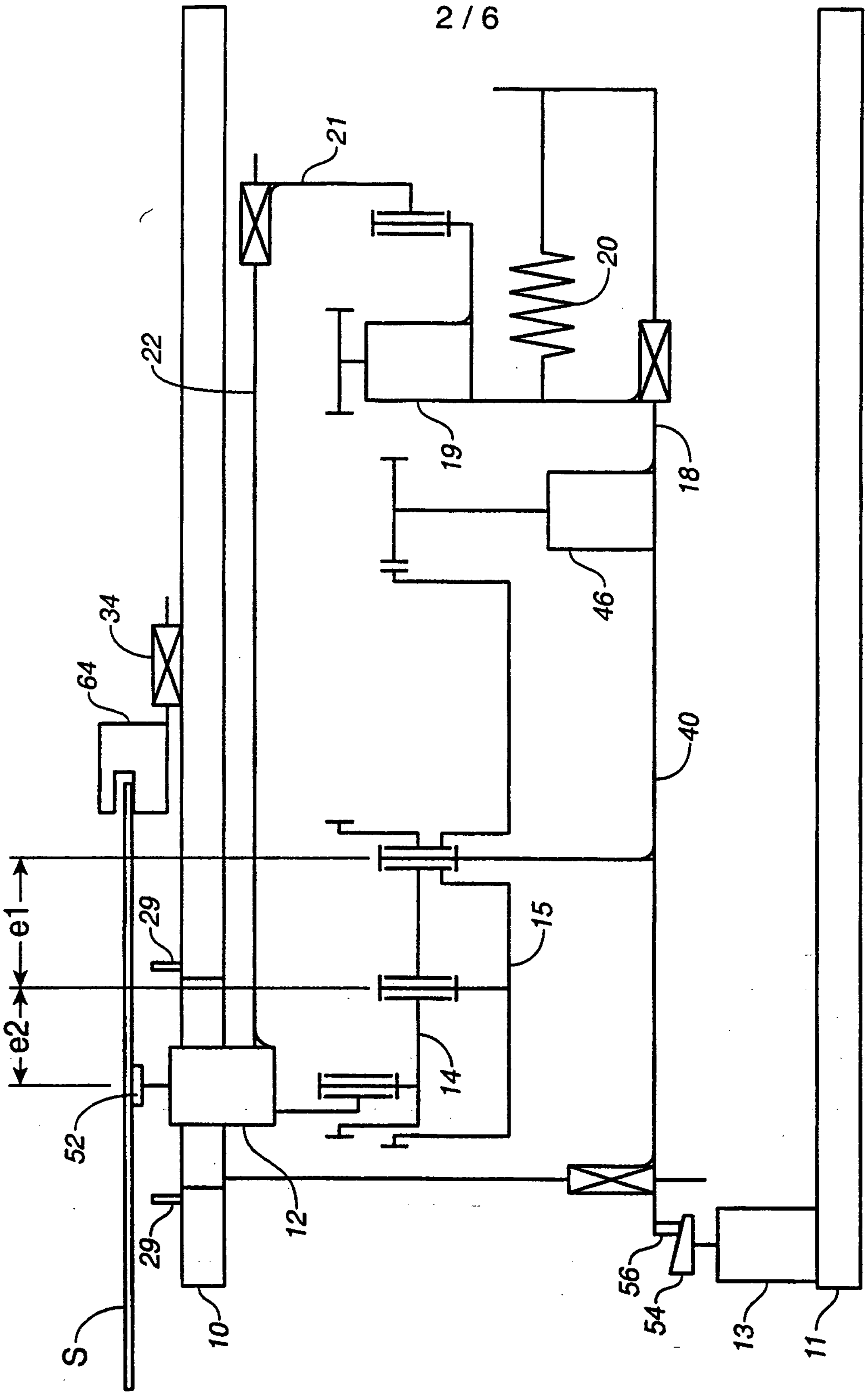

FIG._2

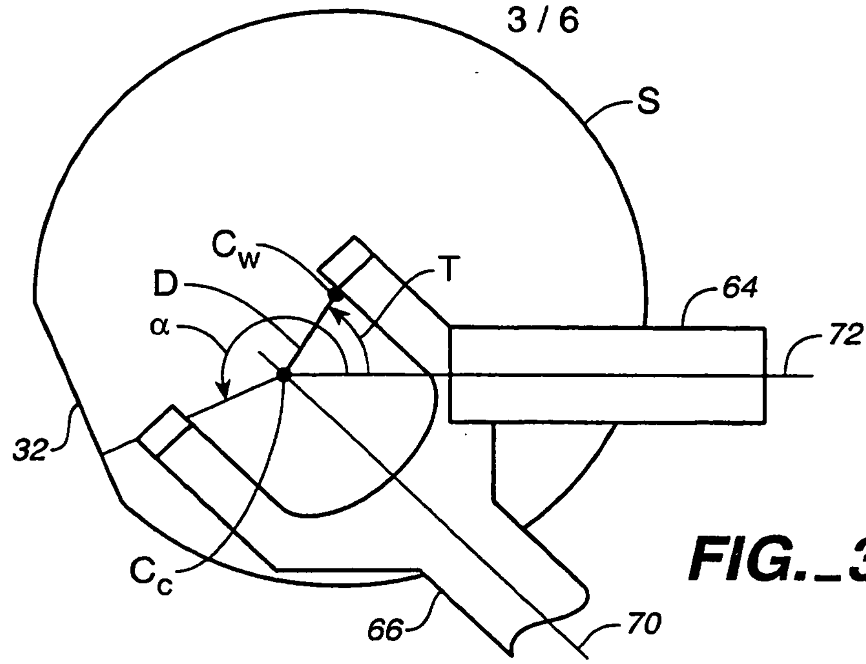
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FIG._3

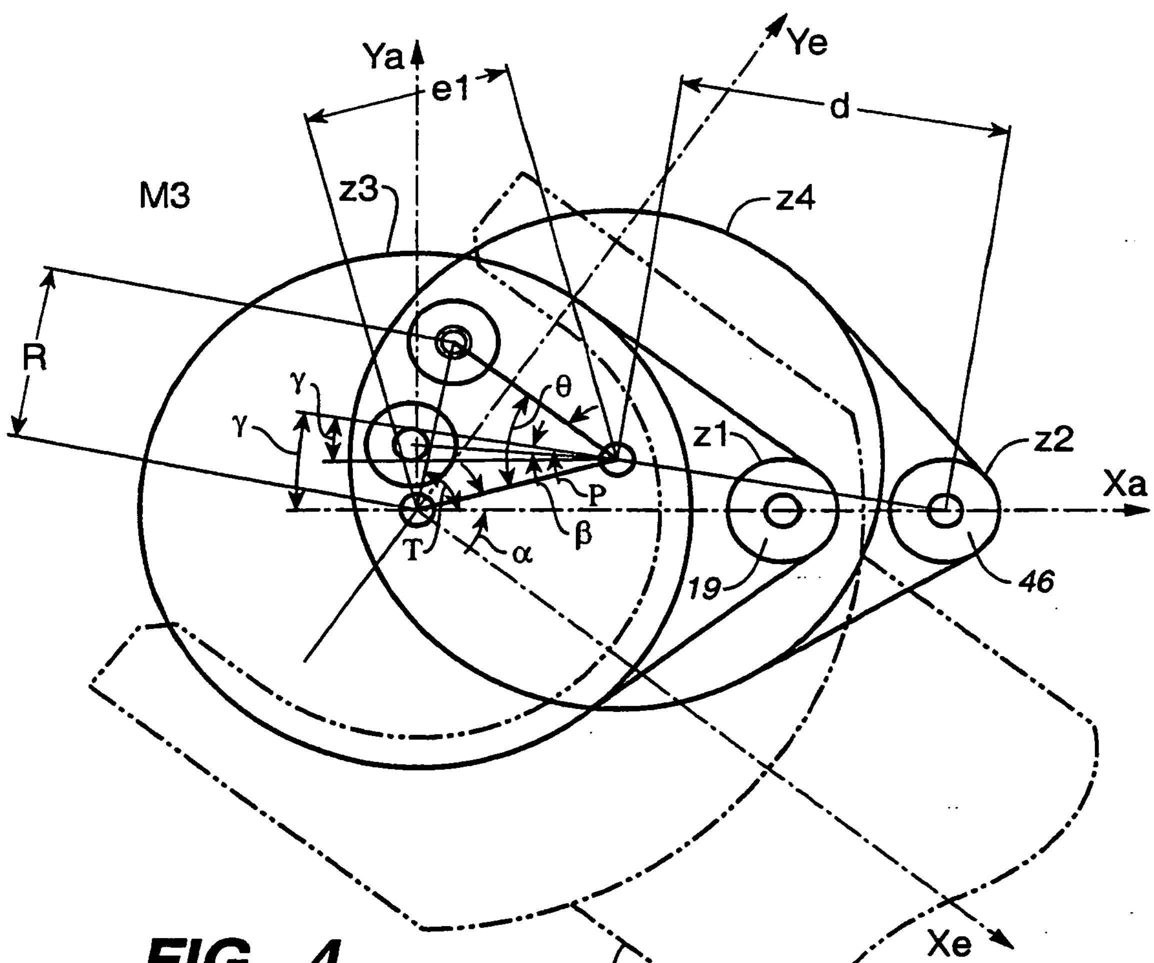
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FIG._4

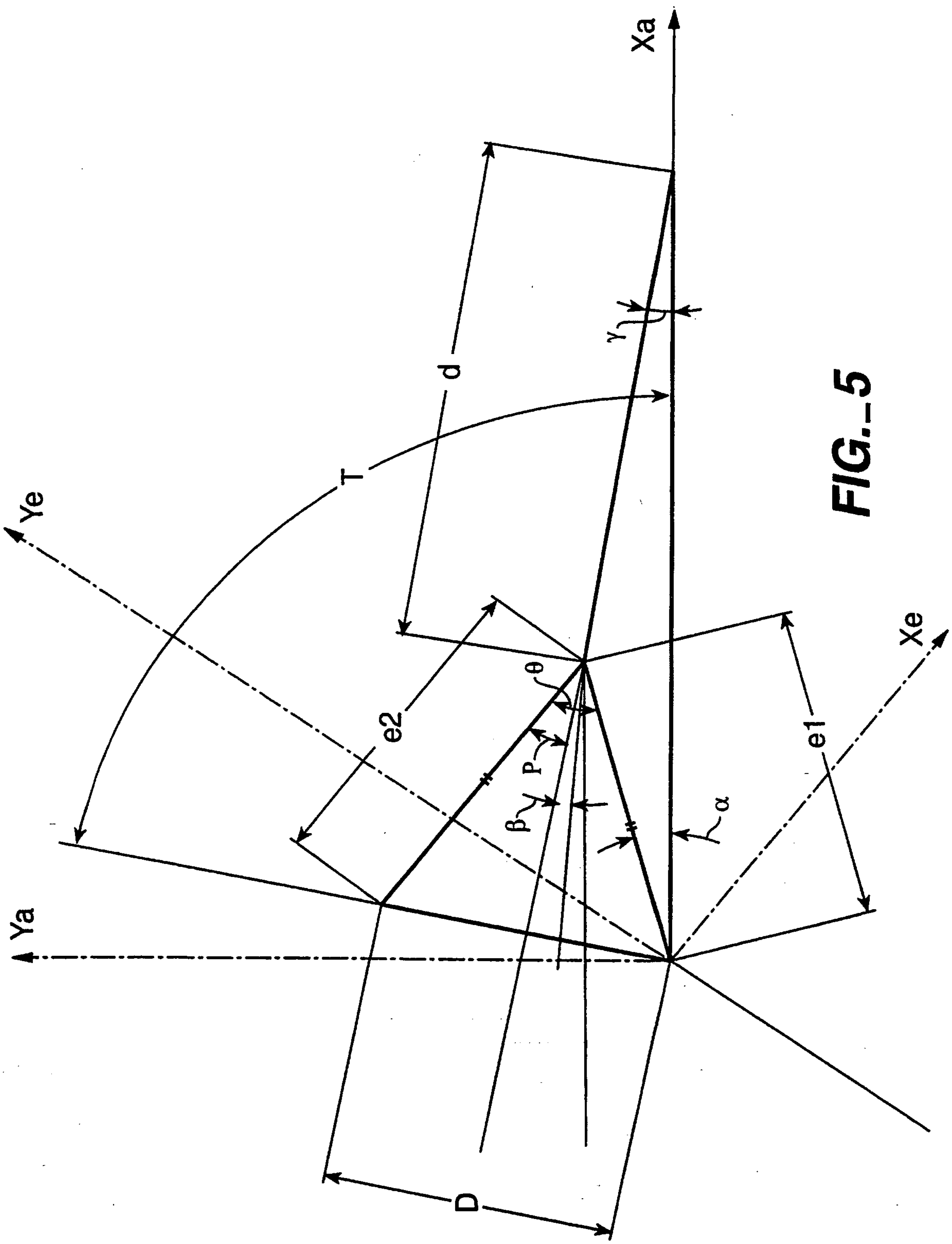

FIG._5

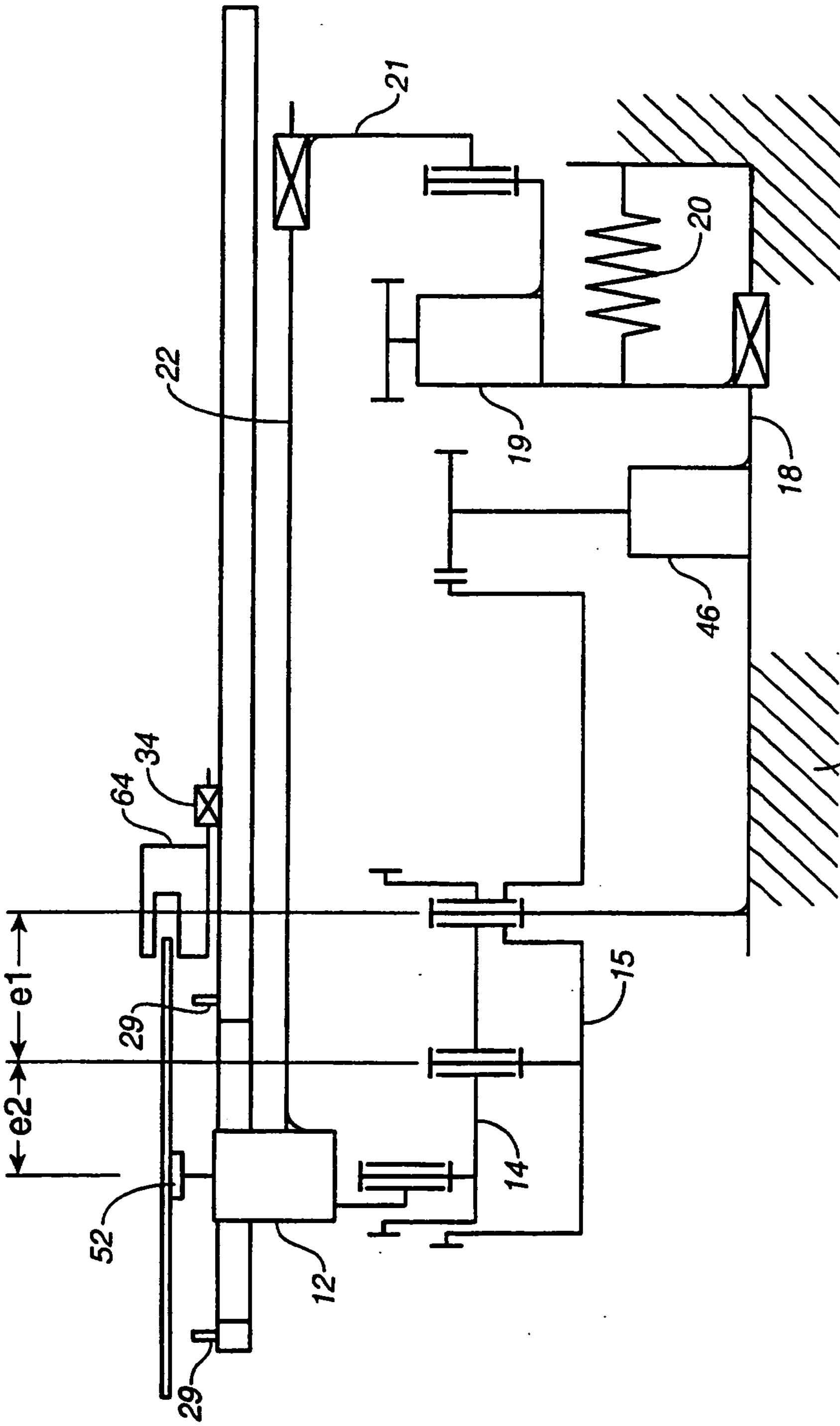

FIG._6

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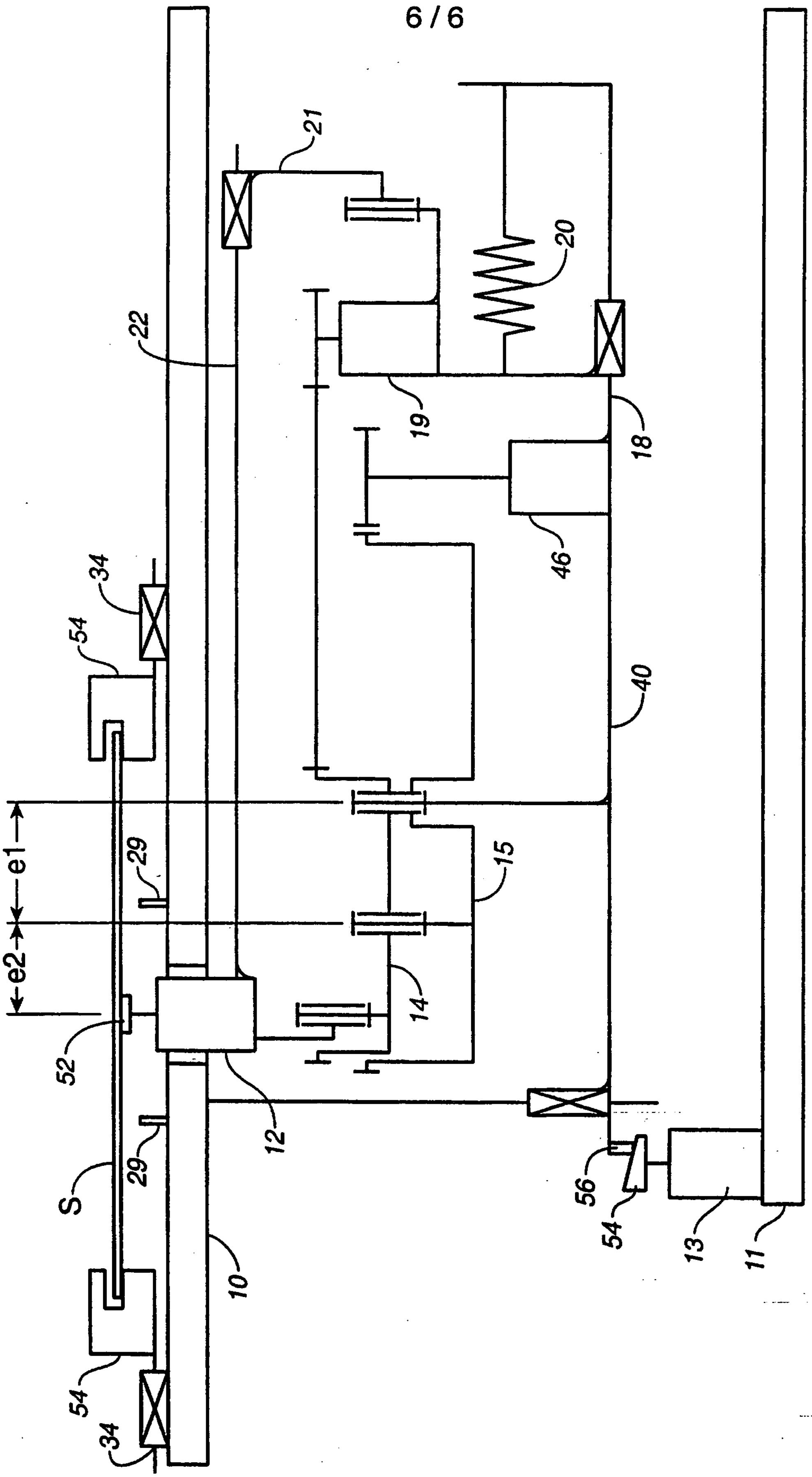
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FIG._7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/07928

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :B25J 15 06
US CL :414/744.4
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 414/744.1. 744.4. 744.5. 744.6. 935. 936

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4,955,780 A (SHIMANE et al) 11 September 1990 (11/09/90), see entire document.	1-13
A	US 5,054,991 A (KATO) 08 October 1991 (08/10/91).	

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents.
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
10 JUNE 1999	22 JUL 1999

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